

ELECTRONIC FUNDAMENTALS

EXPERIMENT LESSON 35

VOLUME AND TONE CONTROL EXPERIMENTS



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Experiment Lesson 35

INTRODUCTION

When a radio receiver has a flat frequency response, the sound from the loud speaker has the same proportion of bass and treble loudness as that put into the microphone at the broadcast station. Tone controls, or variable tone compensation circuits function to change the frequency response of the radio receiver and thereby alter the proportion of bass and treble loudness. Not all tone compensation circuits afford tone control. Some provide compensation that cannot be varied. These are for equalizing phonograph pickups and other devices. However, all tone compensation circuits follow the same basic principles of operation.

All tone compensation circuits are basically filter circuits. Filter circuits allow some frequencies to pass and reject others. Tone controls work by varying the pass-reject frequency characteristics of an audio filter circuit. It is possible to design filters to have any one of a large variety of pass-reject frequency characteristics. In this experiment lesson you will build several tone control filter circuits and hear their effect on the tone of the sound from your radio loudspeaker.

Tone control filters may be placed in the path of the audio signal traveling to the speaker. In this case, the filters act directly upon the forward-going signal that is traveling to the loud speaker. Alternatively, the filters may be placed in the feedback path of an amplifier provided with negative feedback. In this case, the filters act upon the signal that is fed back. Because of the filter action, more signal is fed back at some frequencies than at other frequencies. The signal fed back opposes signal in the forward path. In the course of your experiments in this lesson, you will build both the direct and the feedback kind of tone control circuit.

There are two kinds of tone controls. Those that are controlled with a rotary switch by switching components of the filter are called *step controls*. Those that are controlled with a rheostat by varying the value of a resistor in the filter are called *continuously variable controls*. At the completion of these experiments, you will have permanently wired a continuously variable tone control for your radio. Also, you will have installed a phonograph input receptacle in your radio.

EQUIPMENT NEEDED

One 0.02- μ f capacitor

One 270- μ f capacitor

One 100 k-ohm $\frac{1}{2}$ -watt resistor

One 0.5 megohm potentiometer

One Phono receptacle

Hookup wire

Cardboard (for amount of cardboard see Experiment 35-2)

Radio chassis

JOB 35-1

To prepare for the experiments.

Procedure.

Step 1. Unsolder and remove the 0.25- μ f audio test-point capacitor that is connected to pin 3 of the 6K6. Do this to make room for mounting a temporary terminal strip.

Step 2. Mount a two-terminal strip by means of the screw holding the speaker sup-

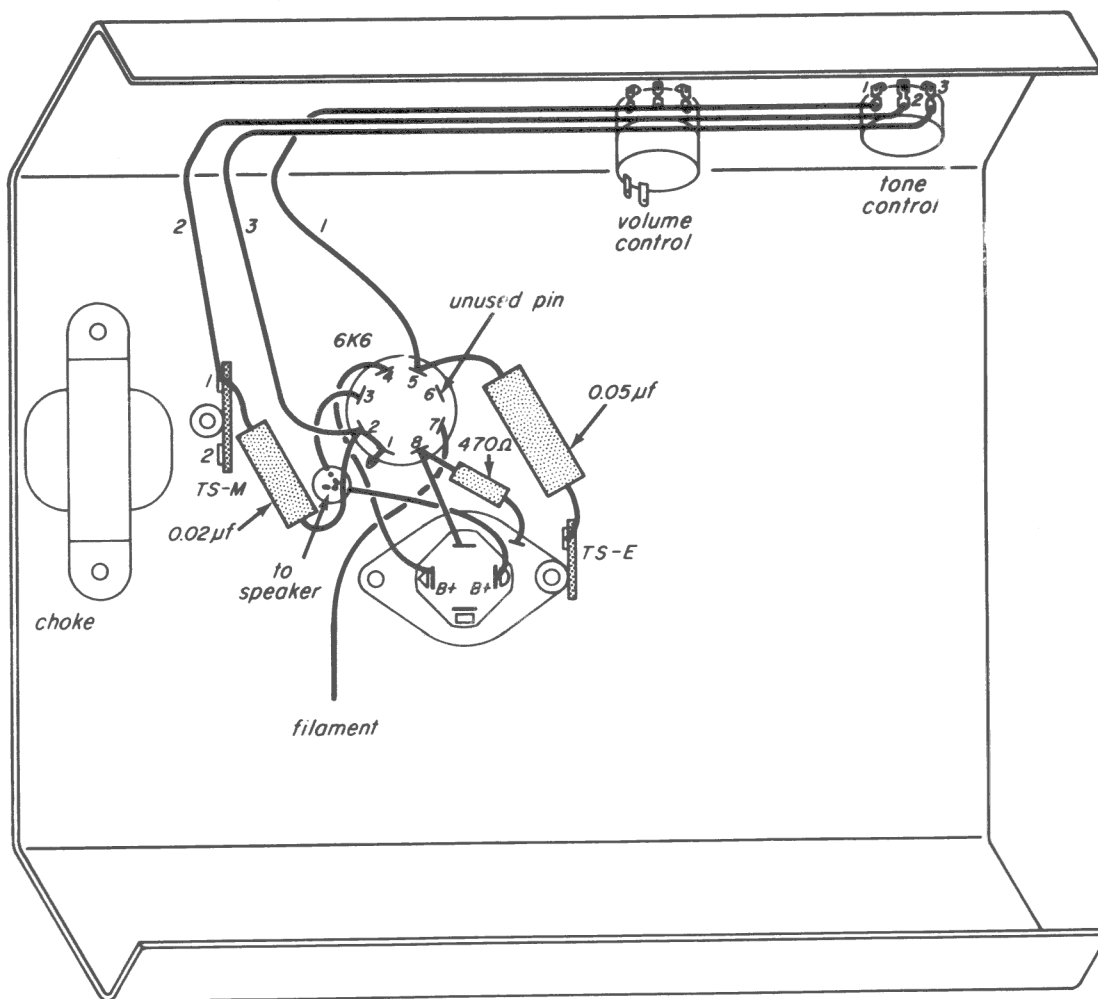


Fig. 35-1

port bracket to chassis (Fig. 35-1). Use the screw nearest the filter choke. This terminal strip will be referred to as TS-M.

Step 3. Remove the 0.01- μ f capacitor that is connected from pin 3 of the 6K6 to chassis. The 0.01- μ f capacitor serves to augment the transformer-coupled plate load for the 6K6 tube. Your receiver will operate without this capacitor, and you will need it for the experimental tone control circuits.

Step 4. Remove the 270- μ f capacitor that is connected from TS-E to chassis. (See Fig. 35-1 for the location of TS-E.) The 270- μ f capacitor serves to bypass r-f voltage that reaches the audio stage and thus prevent r-f regeneration. Your receiver should operate without this capacitor and not regenerate r-f, at least on some stations. You will need the 270- μ f capacitor for the experimental tone control circuits that you are going to build.

Step 5. Connect a piece of hookup wire from terminal 2 of the tone control (Fig. 35-1) to terminal 1 of TS-M. Dress this wire as shown in Fig. 35-1. We will refer to this wire as lead 2.

Step 6. Connect a piece of hookup wire from terminal 3 of the control to pin 2 (ground) of the 6K6. Dress the lead as shown in Fig. 35-1 and allow enough slack for the wire to reach TS-M later on. We will refer to this wire as lead 3.

Step 7. Unsolder and remove the 470 k-ohm grid leak resistor that is connected from pin 5 of the 6K6 to chassis.

Step 8. Connect a piece of hookup wire from terminal 1 of the control to pin 5 of the 6K6. Dress the lead as in Fig. 35-1. This wire will be referred to as lead 1.

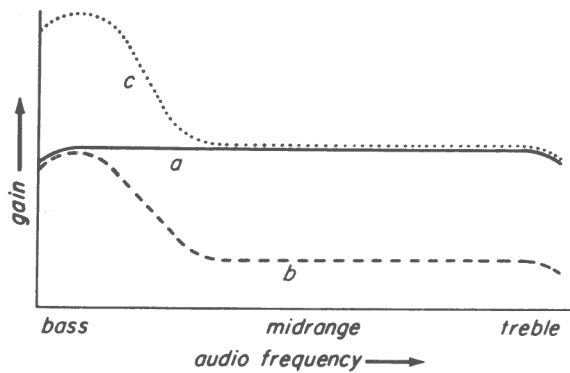


Fig. 35-2

INFORMATION

Almost all tone controls work by reducing gain for some frequencies below the natural flat-response-gain of the receiver, while leaving the gain for other frequencies at the natural flat-response level. As shown in the graph Fig. 35-2, a receiver might have a natural flat-response-gain as at *a*. A bass boost tone control might function as at *b* to lower the gain at all frequencies except the bass frequencies. It would probably not function as at *c* to raise the gain for bass frequencies above the natural flat-response level, leaving gain at the flat level for all other frequencies. Nevertheless, when the tone control in a practical circuit is operated, it may seem to boost the bass frequencies, when in fact what it actually does is cut middle frequency and treble frequency tones. A tone control that produces this type of effect attenuates *all* frequencies when it is in its extreme counterclockwise position. The effect of attenuating all frequencies is shown by curve *a* in Fig. 35-3. Notice that this curve shows all frequencies at a level much lower than the normal level shown by curve *a* in Fig. 35-2. When the tone control that attenuates all frequencies in its counterclockwise position is turned to its ex-

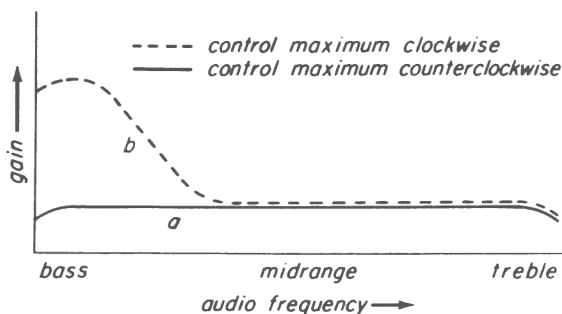


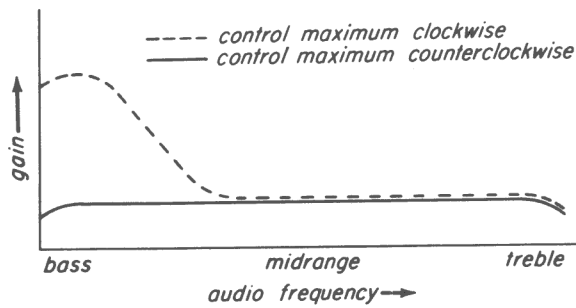
Fig. 35-3

treme clockwise position, it does not attenuate the bass frequencies. As shown in curve *b* of Fig. 35-3, bass frequencies remain at the normal level. However, middle frequencies and treble frequencies are attenuated.

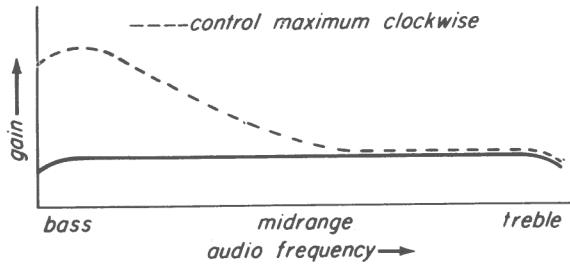
Now let us assume that the tone control is turned back to its extreme counterclockwise position, and the response of the radio receiver is once more like the response shown by curve *a* of Fig. 35-3. And let us assume that a stage of amplification is added to the radio receiver so that the amplitude of curve *a*, Fig. 35-3, is raised to the amplitude of the normal response of the set, which is shown in curve *a* of Fig. 35-2. So far as the listener is concerned, there is no difference between the flat response that has been attenuated and amplified and the normal response. However, by means of turning the tone control on the receiver to its extreme clockwise position, the situation can be changed so that the bass is no longer attenuated. Now the result is that all frequencies are amplified considerably, but the bass is not reduced at all. In other words, when the tone control is turned from its extreme counterclockwise position to its extreme clockwise position, it seems that the bass is being boosted. The listener cannot tell that in reality the bass is being attenuated less.

When a tone control attenuates all frequencies, we say that the flat-response gain level of the receiver is lower. Inserting the tone control into the circuit introduces this loss, and the loss itself is called *insertion loss*. Insertion loss is the difference between the normal flat response gain, as shown by curve *a* of Fig. 35-2 and the reduced flat-response caused by the tone control, as shown by curve *a* of Fig. 35-3. You will find insertion loss in some of the tone control filters that you are going to build.

Design engineers can compensate for insertion loss by adding an extra stage of amplification, often called the *tone-control amplifier*, but this is not the practice for run-of-the-mill radio receivers. Some of the filters you will build are not suitable for run-of-the-mill receivers because they require an extra amplifier. Also, the filters



(a)



(b)

Fig. 35-4

you build are intended to illustrate basic principles. Some may not have all the components required to *shape* the response curve ideally. The response curves in Fig. 35-4a, representing two settings of a tone control, show the ideal curve for bass boost. When the tone control dial on the front panel of the receiver is set in its extreme clockwise position, the response of the amplifier is as shown by the dashed line. Only the bass is boosted. The curves at *b* result from a tone control circuit that is not ideally designed. As shown by the dashed line at *b*, mid-range tones get boosted as well as bass tones in the extreme clockwise *bass-boost* position of the control. Boosting the mid-range tones introduces a peculiar effect. When a tone control changes mid-range response, the control seems to alter the *loudness* of the sound as well as the tone. But a tone control should not seem to alter loudness. Ideally, a tone control should change bass and/or treble response without changing mid-range response.

The ideal tone control is to be found in high-fidelity (Hi-Fi) radios and sound systems but not in the run-of-the-mill radio receivers. This is because filter circuits designed to produce the ideal tone control responses invariably introduce large insertion losses and require additional stages of amplification.

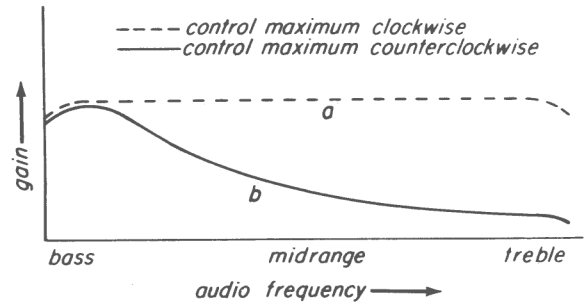


Fig. 35-5

Run-of-the-mill tone controls differ from ideal controls in respects other than response shape. In Fig. 35-5 are two response curves representing the two extreme positions of the first tone control circuit that you will build. This is the circuit that you will finally wire permanently into your radio, and it is the circuit found most often in radio receivers other than high-fidelity receivers. At one setting of the control, the filter is effectively out of the radio circuit and the natural flat response of the receiver prevails (curve *a*). At the other extreme position, the treble and mid-range tones are attenuated more than the bass tones (curve *b*). What you hear when you turn the control is different than what you hear when you turn an ideal bass-boost control. As you advance the control of an ideal bass boost circuit, bass sounds become gradually more noticeable. Advancing the control associated with Fig. 35-5 produces the sensation of decreasing treble, mid-range, and volume. The lost volume can be made up for by resetting the receiver volume control. Once set in the non-flat position, the circuit produces the effect of bass boost; it is sometimes called a bass boost circuit. However, understand that the audible sensation of turning the control in this circuit and the circuit response curve are not exactly like the ideal bass boost response, Fig. 35-2b. However, the circuit being discussed here has the advantage of minimum insertion loss.

Ideally, a tone control should not change mid-range response. An ideal tone control should seem to boost or attenuate the range of frequencies it is intended to make seem louder. For example, the ideal tone-control we discussed seems to boost bass, and is called a bass boost tone control. Other ideal controls are called *bass-attenuate*, *treble-boost*, and *treble-attenuate* controls. As you see, these

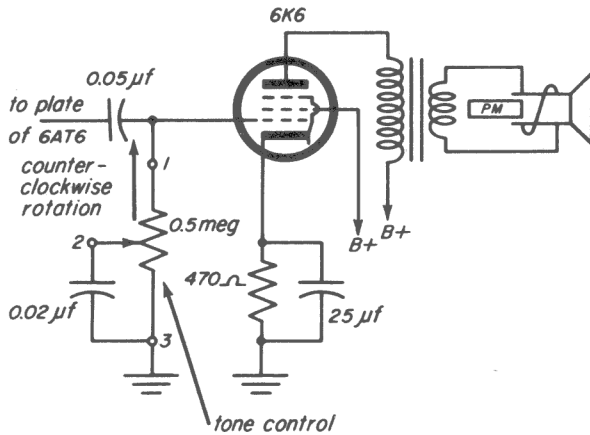


Fig. 35-6

terms do not apply precisely to some nonideal tone controls. Therefore, we will not use the conventional terms to describe the workings of the nonideal tone control circuits that you will build in these experiments. Instead, we will completely explain how each circuit is supposed to affect receiver response.

EXPERIMENT 35-1

To build and hear the effect of a continuously variable tone control circuit that attenuates treble and high mid-range tones, thus accentuating bass and low mid-range tones. This is the circuit of the permanent tone control for your receiver.

Information. A schematic of the circuit you will be working with is shown in Fig. 35-6. The wiring is shown pictorially in Fig. 35-1. The filter is made up of the tone-control resistor and the 0.02-μf capacitor connected to the moving contact, terminal 2, and it is in the main signal path. The tone control resistor takes the place of the 470 k-ohm fixed resistor grid leak that you have removed (Job 35-1). The signal input voltage to the 6K6 develops across the tone control resistor. With the control in the extreme clockwise position, the moving contact (terminal 2) of the control is at terminal 3 and the 0.02-μf capacitor is shorted out. As the moving contact advances counterclockwise (c.c.) toward terminal 1, the 0.02-μf capacitor is shunted across more and more of the resistance of the control. Thus the capacitor is in position to bypass more and more of the signal voltage developed across the resistance of the control. However, the capacitor

bypasses high-frequency signals much more than low-frequency signals because its ohmic reactance is lower for high frequencies. It hardly bypasses the very low frequencies at all. When the moving contact is in the extreme counterclockwise position most signal in the treble range is bypassed and bass is most accentuated.

Procedure.

Step 1. Solder the foil-end lead of your 0.02-μf capacitor to pin 2 of the 6K6. Solder the other lead of the capacitor to terminal 1 of TS-M.

Step 2. Turn on your radio. Tune in a station—preferably music. Operate the tone control; examine the effect of the tone control in the light of the information at the start of this lesson.

EXPERIMENT 35-2

To make a simple speaker baffle and observe that it improves the response of the receiver to bass tones.

Information. Your receiver is not mounted in a cabinet and it has no baffle to prevent cancellation of the front waves from the speaker by the sound waves emanating from the rear surface of the speaker cone. The bass response is not as good as it would be if the set were mounted in a cabinet. This circumstance makes it more difficult for you to examine the effect of the tone control circuits that you build. To get around the difficulty, you can cut out a simple cardboard baffle for your speaker. As you rotate the tone control to examine its effect in the circuits you build, you can hold the baffle in place against the speaker frame.

Procedure.

Step 1. Cut out the baffle template that you will find in the back of this booklet. Paste the template on a sheet of cardboard, preferably thick cardboard such as the corrugated kind of which boxes are made.

Step 2. Trim the board to the size of the template. Cut out a hole along the dashed line.

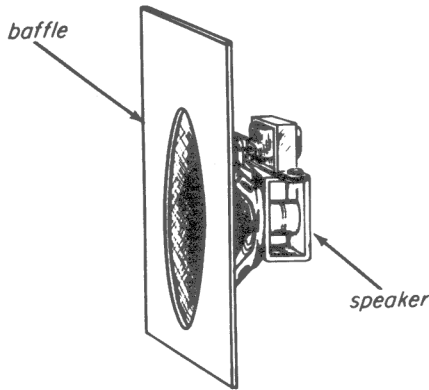


Fig. 35-7

Step 3. Tune in a station on your radio—preferably music—and set the tone control at the full bass position (counterclockwise).

Step 4. Hold the baffle in place momentarily against the front of the speaker as shown in Fig. 35-7. Note that the bass response improves while the baffle is in place.

EXPERIMENT 35-3

To build and hear the effect of a bass-accentuation tone control circuit with the filter in a negative feedback path.

Information. A schematic of the circuit you will now build is shown in Fig. 35-8. The effect upon tone of the control in this circuit should be similar to that in the circuit you built in Experiment 35-1. However, this circuit works differently. In this circuit the filter is made up of the 100 k-ohm resistor, the two capacitors (0.01 and 0.02- μ f) in series combination, and the 0.5-megohm control at the grid of the 6K6. The two capacitors are combined in series to yield the needed value of capacitance—0.007- μ f. A portion of the signal at the plate of the 6K6 is fed back to the grid where it is in a phase opposing the forward-going grid signal. Because of the 0.007- μ f capacitance, more signal voltage is fed back at treble frequencies than at bass frequencies. As a result, the treble portion of the forward-going signal is cancelled more than the bass. The treble is most effectively opposed when the moving arm is positioned counterclockwise (c.c.) at the grid end of the 0.5-megohm control resistor. With the arm at the grid, the most treble signal voltage is fed back.

Procedure.

Step 1. Unsolder the foil-end lead of the 0.02- μ f capacitor from ground at pin 2 of the 6K6.

Step 2. Solder the foil-end lead of the 0.02- μ f capacitor to terminal 2 of TS-M. Also solder to this terminal the foil-end lead of the 0.01- μ f capacitor that you disconnected from its place in your radio as part of Job. 35-1.

Step 3. Solder the other lead of the 0.01- μ f capacitor to the unused pin (pin 6) of the 6K6. Also solder one lead of your 100 k-ohm $\frac{1}{2}$ -watt resistor to this pin.

Step 4. Solder the other lead of the resistor to the plate, pin 3, of the 6K6. The circuit is now wired as shown schematically in Fig. 35-8.

Step 5. Tune in a station (music) and check the operation of the control. Use your speaker baffle.

EXPERIMENT 35-4

To build and hear the effect of a tone control circuit that attenuates treble in one setting of the control and allows for the natural flat response of the receiver in the other setting.

Information. A schematic of the circuit is shown in Fig. 35-9. The 270- μ f capacitor feeds back only treble signal voltage. Most treble is fed back with the moving arm of the

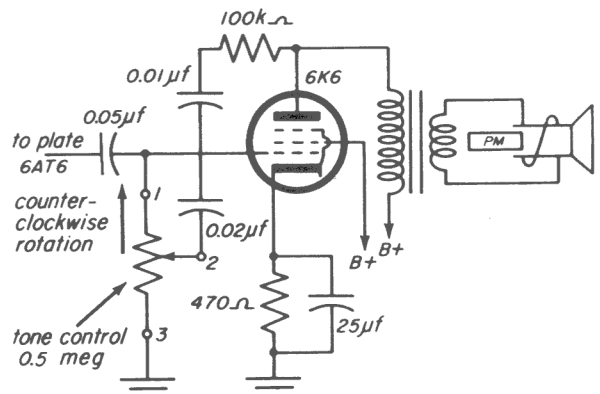


Fig. 35-8

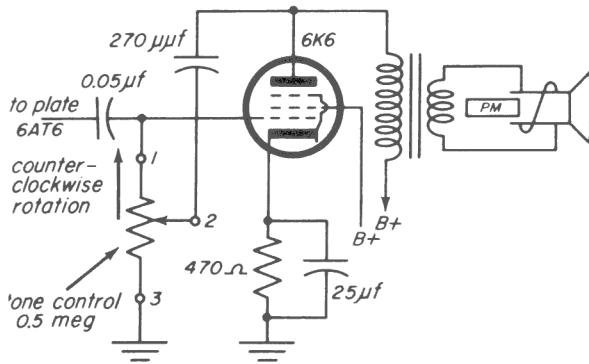


Fig. 35-9

control at the grid; treble is most attenuated with the arm at the grid.

Procedure.

Step 1. Unsolder and completely remove the 0.01-μf capacitor, the 0.02-μf capacitor, and the 100 k-ohm resistor.

Step 2. Unsolder lead 2 from terminal 1 of TS-M. Solder lead 2 to pin 6, the unused pin of the 6K6. Also solder one lead of your 270-μmf capacitor to pin 6.

Step 3. Solder the remaining lead of the 270-μmf capacitor to the plate, pin 3, of the 6K6. The circuit is now wired as in Fig. 35-9.

Step 4. Tune in a station (music). Rotate the control and hear its effect—flat response in the clockwise position, treble cut in the counterclockwise position.

EXPERIMENT 35-5

To build and hear the effect of a tone control circuit that attenuates bass and mid-range tones thus accentuating treble in one position of the control. In the other position of the control, the receiver has a flat response at a lower level than the natural flat response.

Information. A schematic of this circuit is shown in Fig. 35-10. The filter is in the path of the forward-going signal. Signal voltage of all but the treble range of frequencies is attenuated by the voltage-divider, consisting of R_1 in series with R_2 . The voltage divides between R_1 and R_2 . That portion of the signal voltage which is develop-

ed across R_2 is passed on to the grid of the 6K6. Because R_2 is only one-fifth as large as R_1 , only one-fifth (approximately) of the signal voltage, excepting the treble, from the 6AT6 plate is passed on to the grid of the 6K6. Treble signal bypasses R_1 via the 540-μmf of capacitance made up of 270-μmf capacitors in parallel. Treble signal divides between the resistance of the control and R_2 . Since the resistance of the control can be varied and made less than R_1 , the proportion of treble signal developed across R_2 and passed on, can be varied from a value nearly equal to the signal in the bass and mid-range to a value greater than bass/mid-range. As you rotate the control clockwise, the control resistance decreases and more treble passes on. You will notice that this circuit has a large insertion loss; not much volume can be attained when it is in place.

Procedure.

Step 1. Unsolder and disconnect the 270-μmf capacitor.

Step 2. Remove the lead of the 0.05-μf capacitor that is soldered to pin 5, 6K6. Also unsolder lead 2 from pin 6 of the 6K6 and solder it to pin 5 of the 6K6, where lead 1 is already connected.

Step 3. Connect the 270-μmf capacitor and your spare 270-μmf capacitor in parallel. Connect one lead of the pair to terminal 1 of TS-M and connect the other lead to terminal 2 of TS-M.

Step 4. Unsolder lead 3 from ground at pin 2 of the 6K6; solder it to terminal 2 of TS-M.

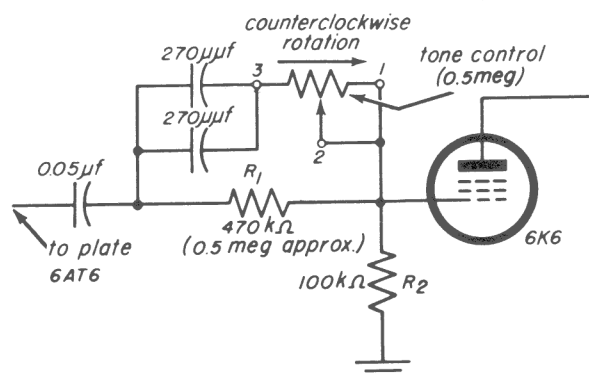


Fig. 35-10

Step 5. Solder the free lead of the 0.05- μ f capacitor to pin 6 of the 6K6.

Step 6. Connect a piece of hookup wire from pin 6, 6K6 to terminal 1, TS-M.

Step 7. Solder your 470 k-ohm $\frac{1}{2}$ -watt fixed resistor between pins 6 and 5 of the 6K6.

Step 8. Connect your 100 k-ohm $\frac{1}{2}$ -watt fixed resistor from pin 5 to pin 2 of the 6K6. The circuit is now wired as shown in Fig. 35-10.

Step 9. Tune in a station. Listen to the effect of rotating the control. If there is some hiss on the station you tune in, you will hear it increase in the treble position of the control because hiss is mostly in the treble range of audio frequencies.

EXPERIMENT 35-6

To build and hear a treble boost /treble cut tone control.

Information. So far you have built tone control circuits to perform only one function—to boost bass, to cut treble, to boost treble. Now you will build a circuit in which a single control performs two of these functions. In this circuit, flat response is obtained in the midposition of the control. If you turn counterclockwise from the midposition, treble attenuates; if you turn clockwise, treble boosts. This circuit is an example of a dual function control. A single tone control can be designed to provide any two response characteristics with flat response, center position.

A schematic of the circuit is shown in Fig. 35-11. All signals but the treble divide in the voltage divider, the 470 k-ohm resistor in series with the resistance of the control. With the moving arm at terminal 3 of the control, treble is shunted past the 470 k-ohm resistor via the 270- μ f capacitors. In this position, treble signal arrives at the grid of the 6K6 in greater strength than bass and mid-range signal—treble boost. When the arm is at terminal 1 of the control, treble is grounded out via the 270- μ f capacitors while bass and mid-range signal remain unchanged—treble cut.

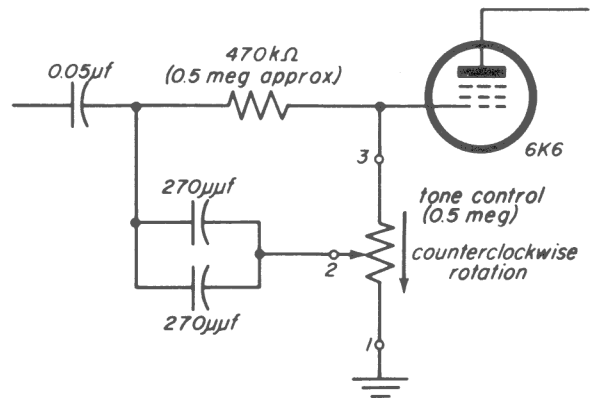


Fig. 35-11

Procedure.

Step 1. Remove the 100 k-ohm resistor, installed in Experiment 35-5.

Step 2. Unsolder leads 1 and 2 from the grid, pin 5 of the 6K6 and unsolder lead 3 from terminal 2 of TS-M.

Step 3. Solder lead 1 to ground at pin 2 of the 6K6, lead 2 to terminal 2 of TS-M, lead 3 to the grid, pin 5, of the 6K6.

Step 4. The circuit is now wired as in Fig. 35-11. Tune in a station and listen to the treble increase in the clockwise position of the control and decrease in the counterclockwise position.

JOB 35-2

To install a phono input receptacle.

Information. The circuit position of the phono input receptacle is shown in the schematic diagram of Fig. 35-12. As you see, a signal applied to the phono receptacle is placed across the volume control, as is the radio signal from the detector.

When a phono operates through the receptacle, you must set the radio tuning dial to a place where no station or noise will be picked up. Of course, the volume and tone controls may be used to regulate sound from the phono as well as sound from the radio.

Perhaps you wonder why we have not included a phone equalizer (a tone compensation circuit) at the phonograph input receptacle. Certainly the sound signal from a

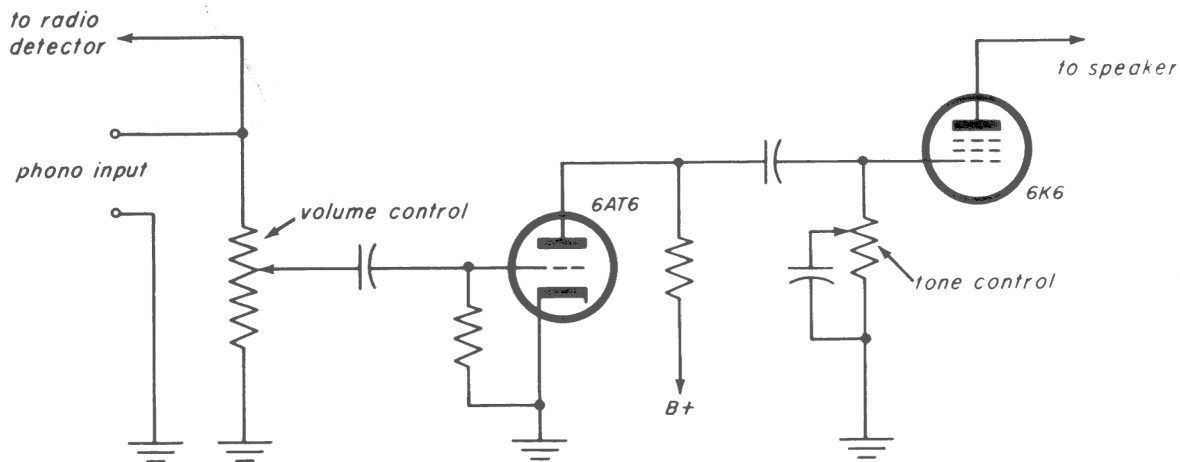


Fig. 35-12

phonograph must be equalized. However, the kind of equalizer that will be required depends upon the design of the phono pick-up. Different equalizers are used with different phono attachments; therefore it is the practice to mount the equalizer circuit in the attachment unit, not in the radio to which it is to be connected. This practice is not followed where the phono is a permanent part of the radio (mounted in the same cabinet).

Procedure.

Mount the phono receptacle in the hole—until now unused—which is in the rear apron of your radio chassis, as shown in Fig. 35-13a. Wire the hot (center) terminal of the receptacle to TS-C terminal 2.

Discussion. The kind of plug that fits the the receptacle is shown in Fig. 35-13b. Most phonograph attachments have this kind of plug on the pickup output cable. If not, one may easily be installed.

JOB 35-3

To wire the permanent tone control for your radio as shown in Fig. 35-14.

Procedure.

Step 1. Completely remove leads 1 and 3.

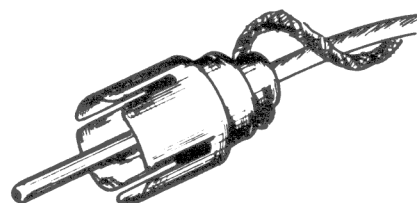
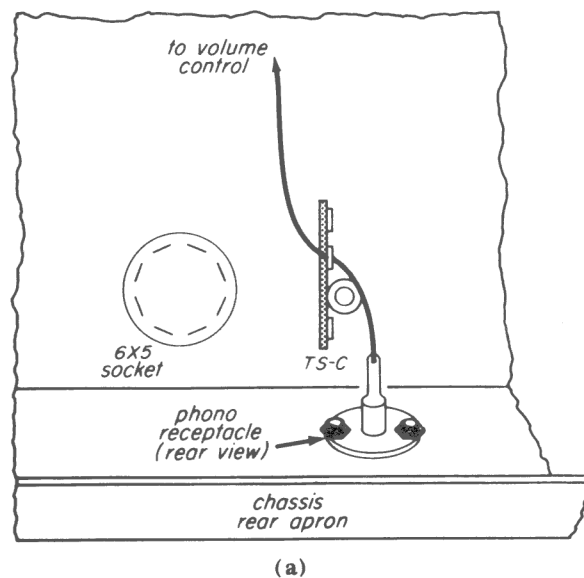
Step 2. Remove the 470 k-ohm resistor, the two 270- μ f capacitors, and TS-M with the short lead connected to it.

Step 3. Unsolder the short lead from pin 6 of the 6K6 tube. Unsolder lead 2 from TS-M

and connect it to pin 5 of the 6K6. Also unsolder the 0.05 μ f capacitor from pin 6 of the 6K6 tube and solder it to pin 5 of the 6K6 tube.

Step 4. Connect a piece of bare hookup wire from terminal 3 of the tone control to chassis at a ground lug of the 6BA6 r-f tube.

Step 5. Unsolder lead 2 from terminal 2 of the control and solder it to terminal 1 of the control.



(b)
Fig. 35-13

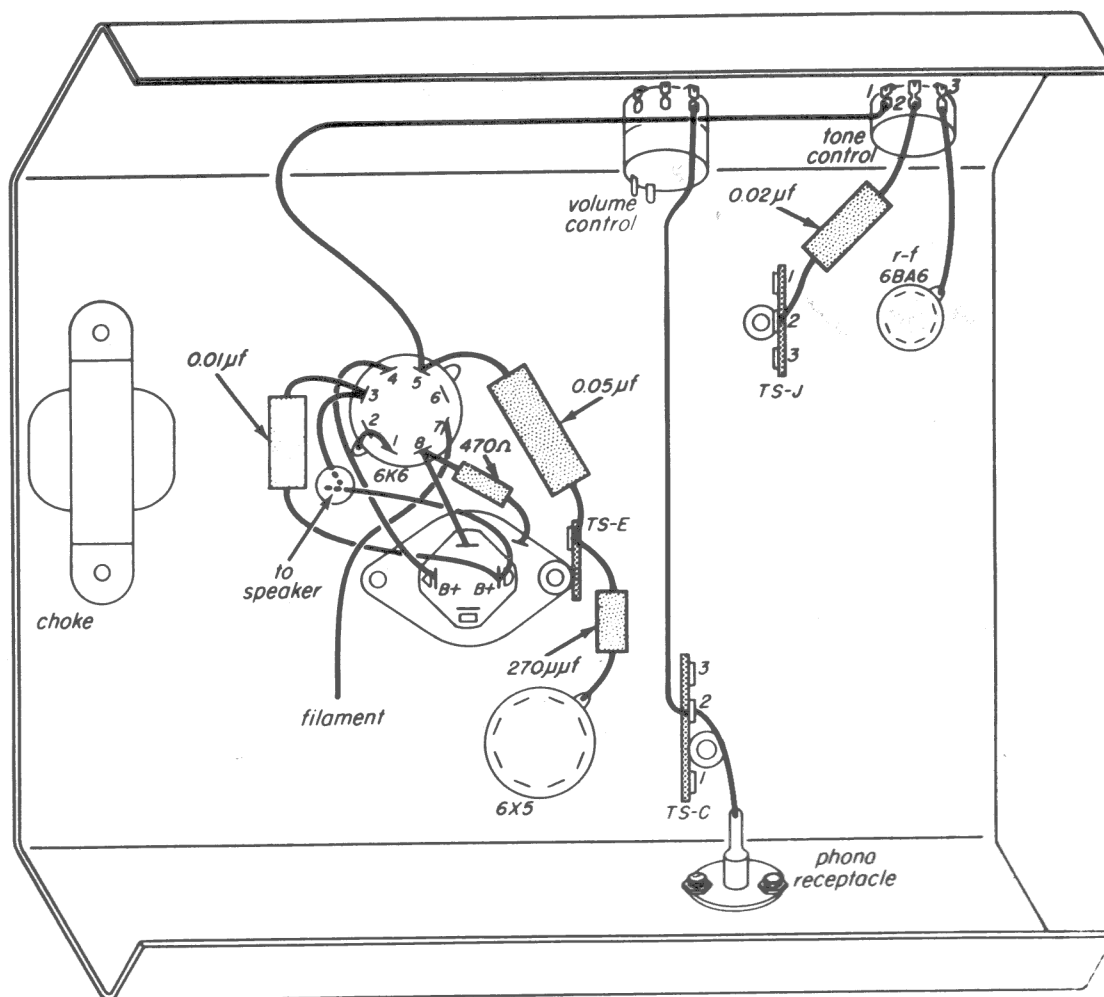


Fig. 35-14

Step 6. Connect the foil-end lead of your 0.02- μ f capacitor to chassis at terminal 2, the center terminal of TS-J. Connect the other lead of the capacitor to terminal 2 of the tone control.

Step 7. Replace the following parts that were removed from their place in your radio as part of Job 35-1:

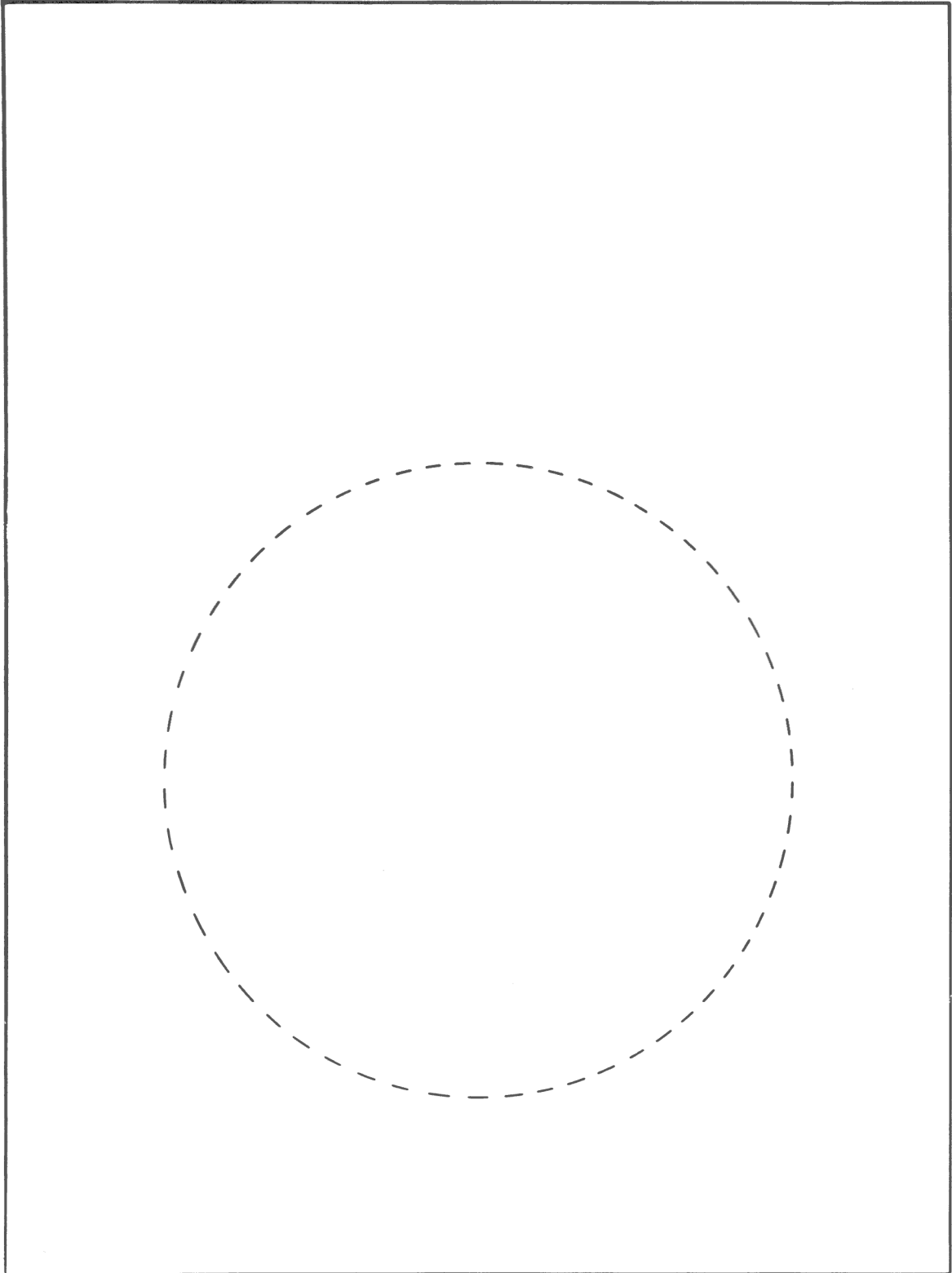
1. The 0.01- μ f capacitor to be connected from the plate, pin 3, of the 6K6 to a B+ terminal of the electrolytic capacitor, as shown in Fig. 35-14.

2. The 270- μ f capacitor to be connected from the terminal of TS-E to ground.

The wiring of the permanent tone control is now complete. The circuit is shown sche-

matically in Fig. 35-6.

Note: The 0.01- μ f capacitor from the plate (pin 3) of the 6K6 was originally connected to ground. Now it is permanently connected to B+ instead of to ground (Step 7, above). The two methods of connection are identical for audio voltages because B+ is at audio ground potential due to the bypass action of the electrolytic capacitor. However, when the capacitor is returned to B+ it has less d-c voltage across it. This is because the d-c voltage at the plate of the 6K6 is almost equal in value to B+. When the two leads of the 0.01- μ f capacitor are connected to points of almost equal d-c voltage, the d-c voltage breakdown potential of the capacitor is less likely to be exceeded, and the capacitor is less likely to break down.



**CUT OUT THIS TEMPLATE FOR A BAFFLE
AND PASTE IT ON A PIECE OF CARDBOARD.**